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AALBORG UNIVERSITY
DENMARK

Hanstholm
DanWEC
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Economic aspects of forecasting and WEC O&M procedures at DanWEC, and an outlook of the commercial value of the O&M tool

December 2018

Executive summary

This report includes a description of the use of the forecast and O&M tools, and the economical advantages related to the use of the tools for DanWEC. The forecast and O&M tools were developed as part of the project "Resource Assessment, Forecasts and WECs O&M strategies at DanWEC and beyond", financed by EUDP. The project period was from 2015 to 2018.

1 Contents

2 Introduction

This report presents the forecast model and the O&M tool developed for the Danish test site for wave energy (DanWEC). It includes results from the project Resource Assessment, Forecasts and wave energy converters' operation and maintenance (O&M) strategies at DanWEC and beyond which has been initiated to deliver detailed information on the environmental conditions at DanWEC and to review implementation of O&M procedures, which will ultimately improve wave energy converters' operation and reduce their costs. The forecast model is based on an hindcast wave model which has been validated against data from wave measuring buoys and it provides six days wave and current prognostic for the test site. The forecast model is coupled with an O&M tool that helps planning operation and reduce costs for users and operators of the test site.

Installation, maintenance and operation of the equipment at the DanWEC test site have been both cost and time consuming and the experience over the last 4 years has shown that improved weather predictions have helped drastically the operation of the test site. The developed forecast and O&M tools have shown to be efficient in reducing the O&M cost.

In the last years, Wavepiston has been testing at the test site. The developer has used the forecast tool for planning operations at DanWEC and has seen the potential of this tool for reduction of cost of energy for the Wavepiston device.

3 History of available forecast tools

In order to plan O&M activities it is of foremost importance to have weather prediction, i.e. predictions of for example wave heigth and current speed to plan the operation with the proper vessel. The open access weather forecast tool provided by DMI was originally used for the O&M at DanWEC. The project “Resource Assessment, Forecasts and wave energy converters' operation and maintenance (O&M) strategies at DanWEC and beyond” gave the possibility to develop a forecast model for DanWEC. Lately a web-based viewer for the forecast model was implemented for both DanWEC as an operator and the developers testing at the site. Those historical steps are described in the following.

3.1 DMI tool used before the project started

Before December 2016, the open access DMI weather forecast was used to perform O&M at DanWEC. The tool is available at the following website: http://www.dmi.dk/hav/udsigter/havprognoser/#fisker. This tool is originally adapted for fishermen. It provides a two days weather prediction of an undefined area of the coast off North-Western Jutland, as shown in Figure 1. It includes prediction of current speed and direction, saltiness level, water temperature, water level, wave height and direction and wind speed and direction.

This tool has the limitations of having a short prediction horizon (only 2 days) and does not allow to zoom in around the DanWEC area, thus providing only a crude geographical resolution.

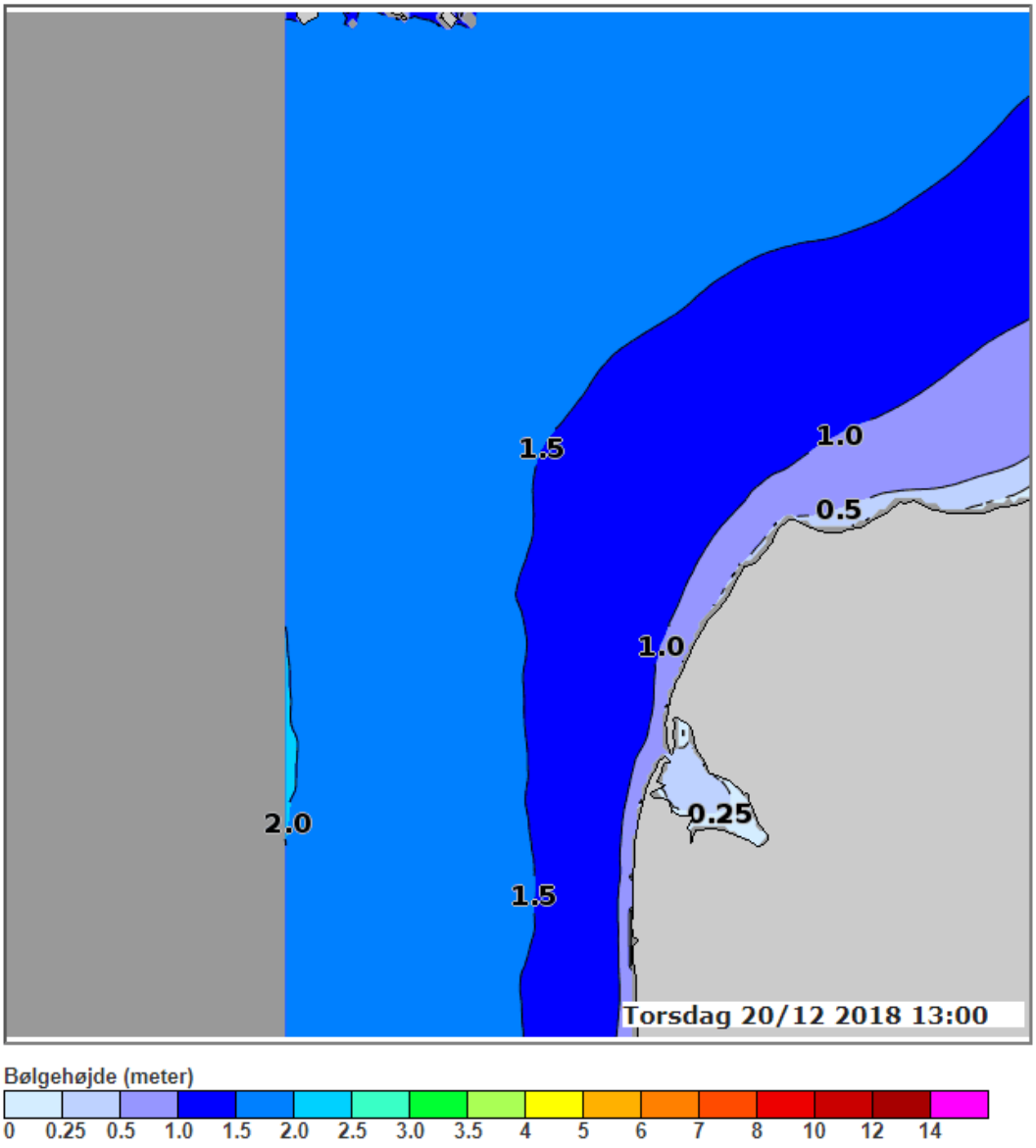

Figure 1: Example of forecasted wave height given by the open access DMI tool.

3.2 First version of the tool developed during the project

The forecast model for the DanWEC test site was developed by DHI and is based on the hindcast model where the grid output resolution is shown in Figure 2 (the reader is referred to [1] for more details on the hindcast model). The forecast model updates a 6 day-horizon twice every 24 hours [2]. The model forcing comprises input from regional DHI models and forecast wind fields. The list of output parameters for the forecast model are given in Table 1.

A python based script was written to read the compressed NTCF4 file (specific format of files sent from the forecast model running on a server at DHI) and display the results in the form of graphs. Those results were made available for DanWEC and then, distributed to the users at the test site. Figure 3 and 4 show typical graphs obtained this way.

The results obtained were clearly an improvement with regard to the national DMI open access weather forecast. The prediction horizon was more than double and a high geographical resolution was available, enabling the comparison with measured data from wave measuring buoys and thus, quantification of the accuracy of the forecast.

Table 1: List of output parameters for the forecast model updated twice every 24 hours throughout the modelling area (Fig. 2)

Parameter	Unit
H_{m0}	[m]
H_{max}	[m]
T_p	[s]
T_{01}	[s]
T_{02}	[s]
Wave direction	[°]
Wind speed	[m/s]
Current speed	[m/s]

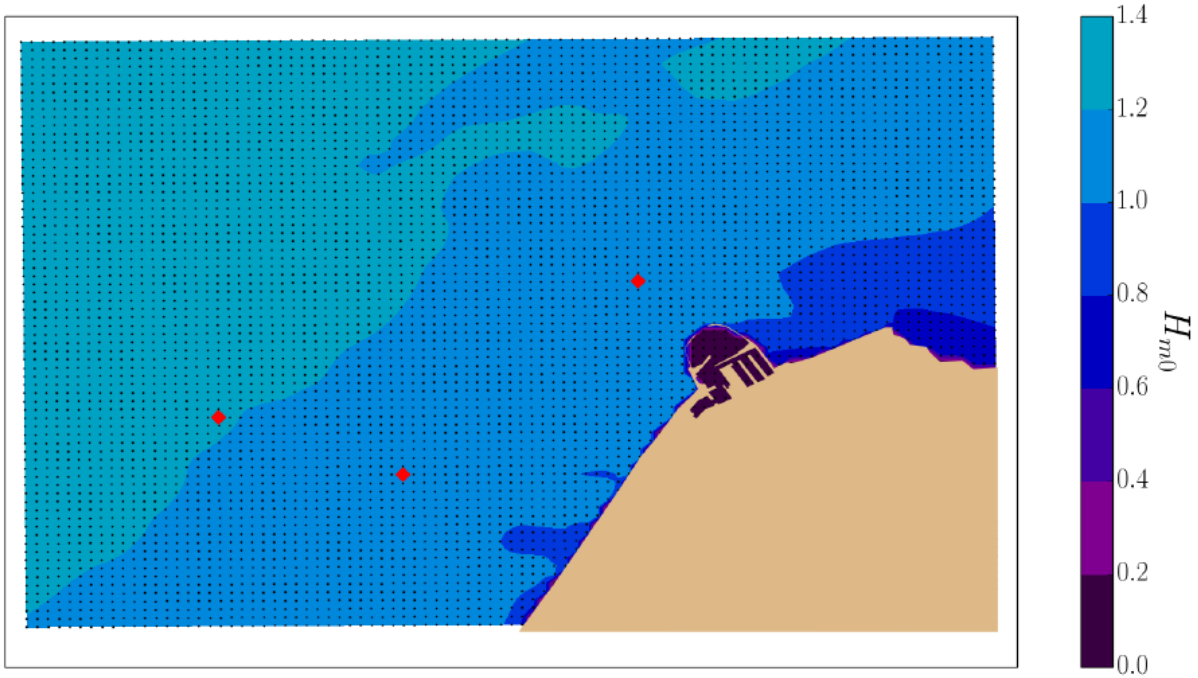

Figure 2: Example of forecast H_{m0} for the total area provided for the forecast model at DanWEC. The three markers mark the position of the wave measuring buoys and the dots correspond to the mesh of the model, i.e. values for each point can be extracted.

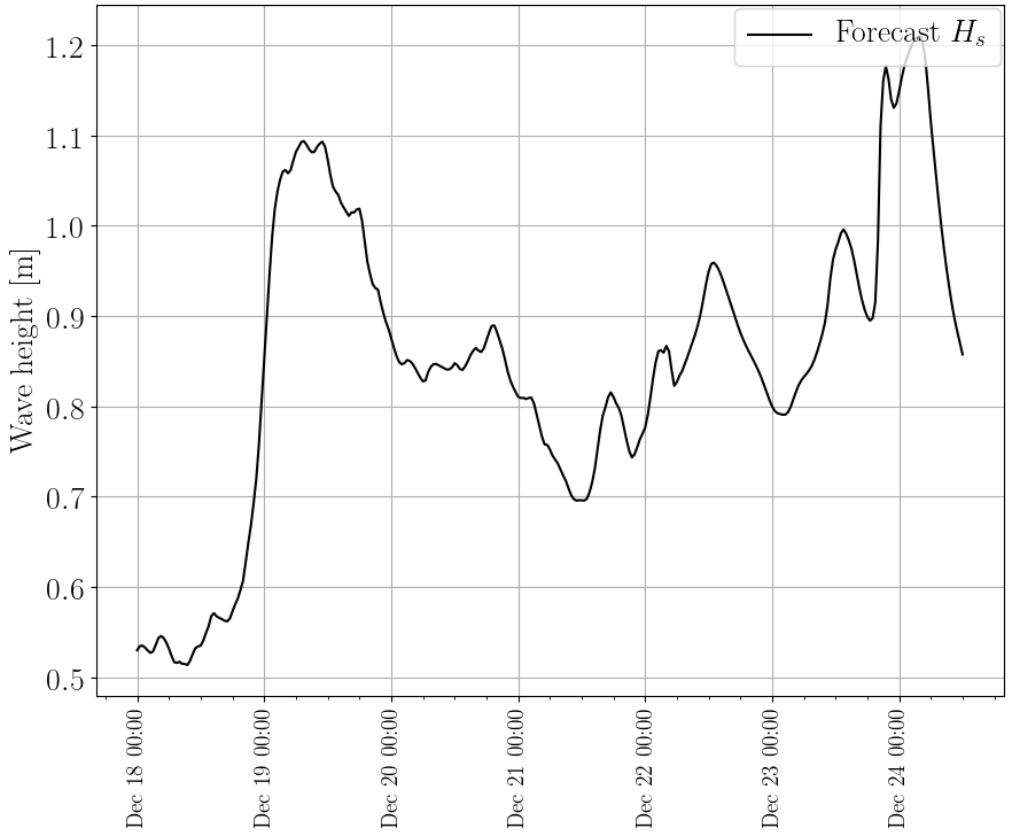

Figure 3: Saved figure from the DanWEC forecast python tool showing the prediction for H_s over the next days.

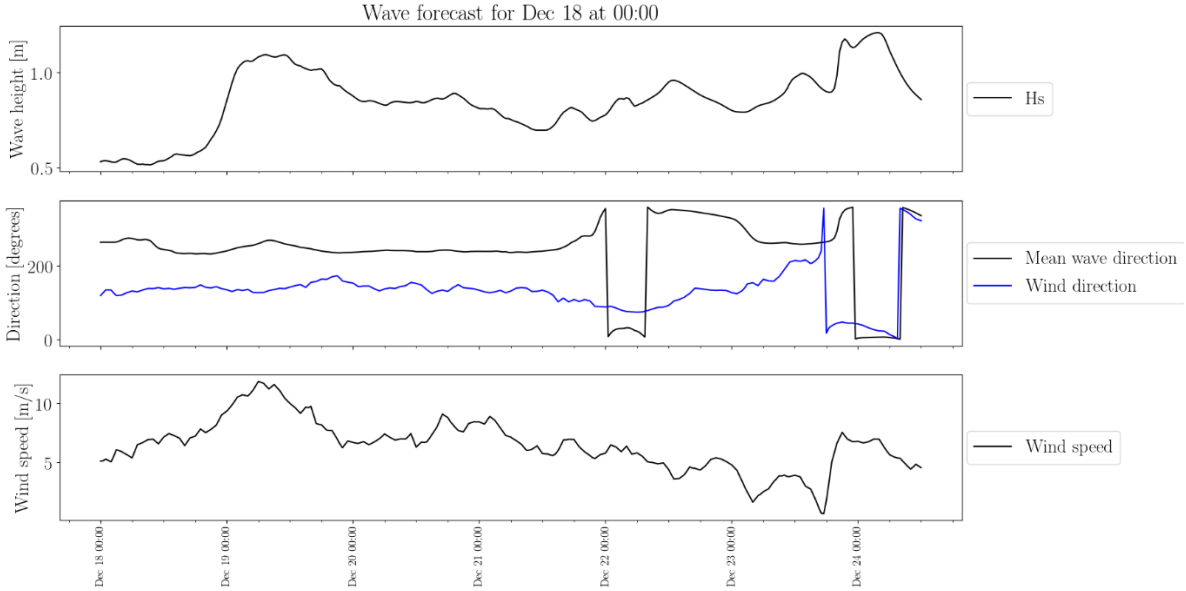

Figure 4: Saved figure from the DanWEC forecast python tool showing the prediction for H_s, mean wave direction, wind direction and wind speed over the next days.

3.3 Second and final version of the tool developed in the project

Lately the forecasted weather conditions at the DanWEC test site was rendered available on a password protected website. The developers testing at the site have direct access to the weather forecast and can therefore plan more efficiently and easily their activities at the site.

The website is using the Django python package and is hosted on the AWS Amazon web service. Figure 3 shows a snapshot of the website, while Figure 4 to 7 shows the graphs that can be downloaded from the site.

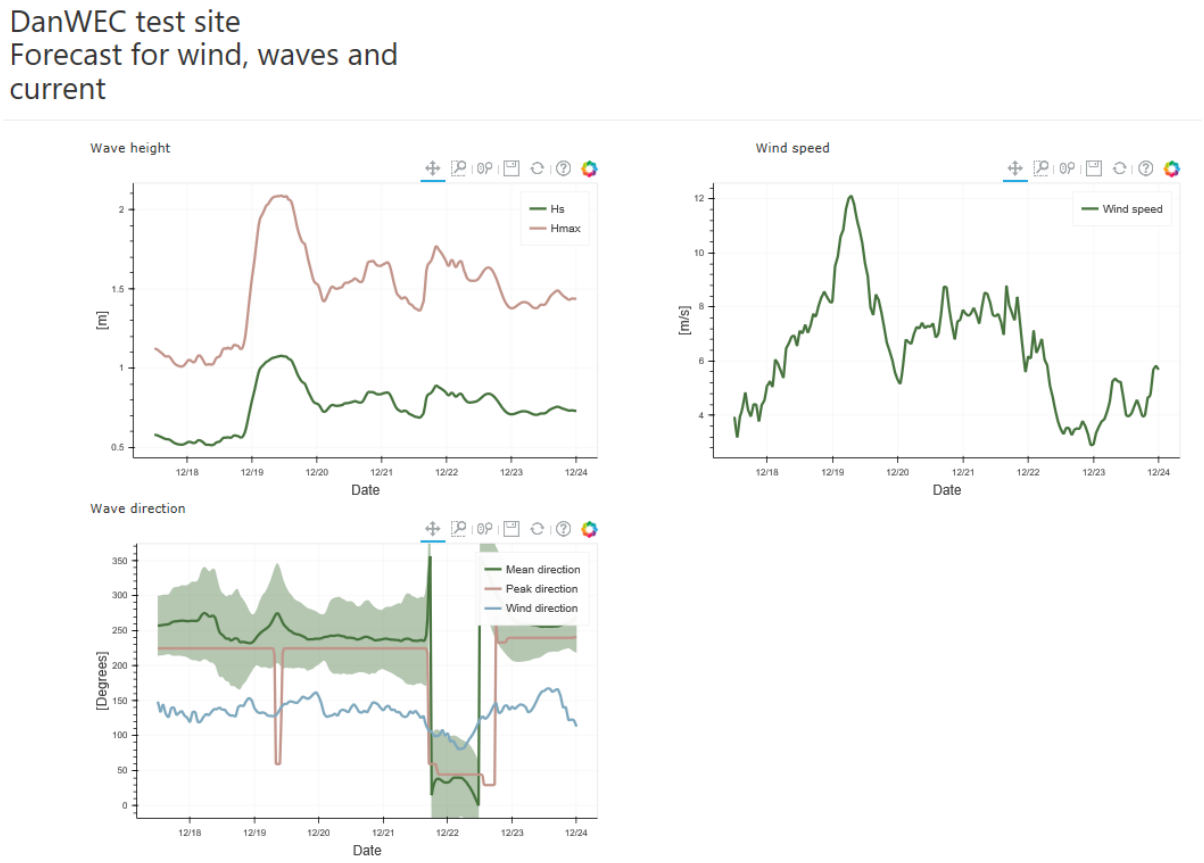

Figure 5: Snapshot of the website for the forecast at the DanWEC test site.

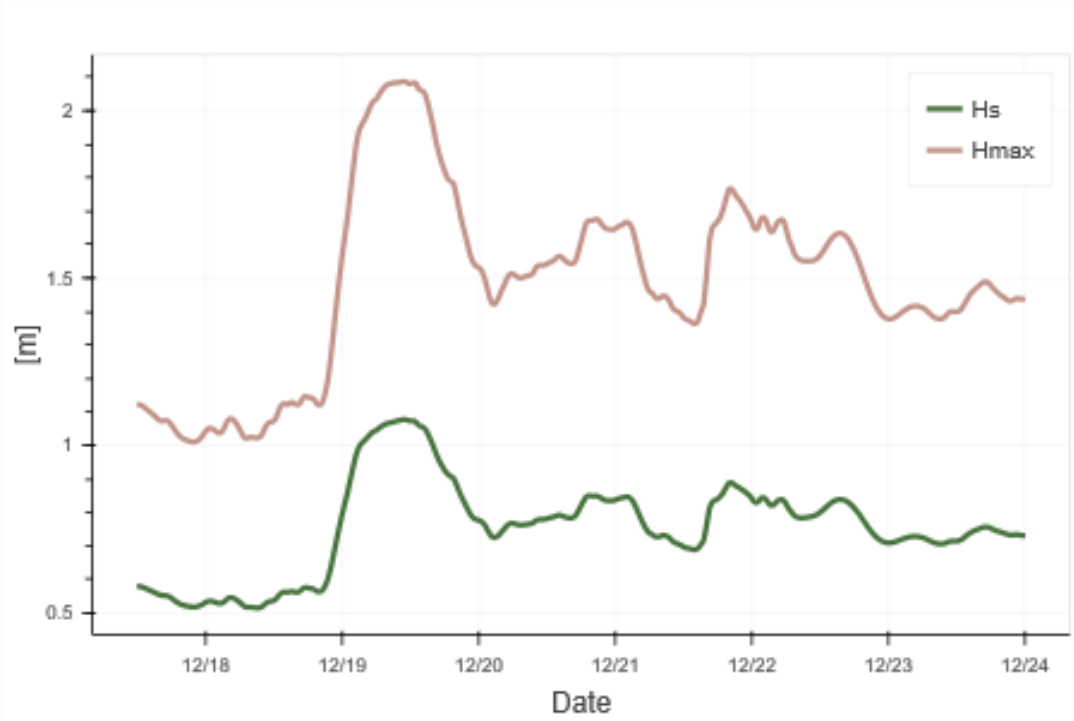

Figure 6: Saved figure from the DanWEC forecast website showing the prediction for both H_s and H_{max} over the next days.

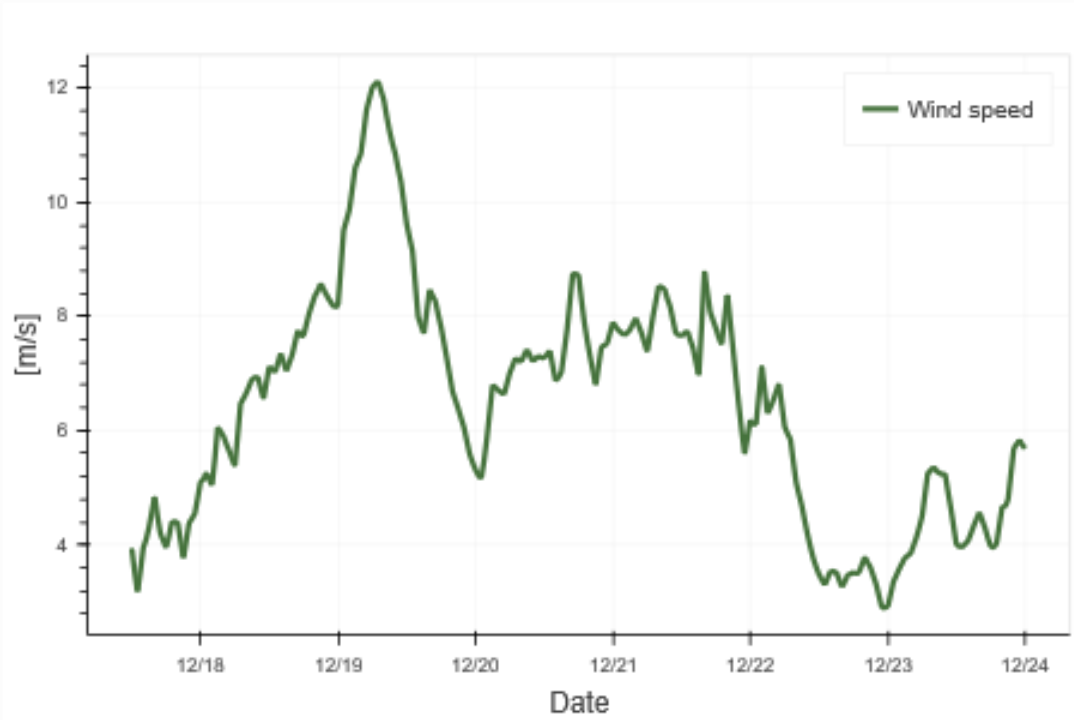

Figure 7: Saved figure from the DanWEC forecast website showing the prediction for the wind speed over the next days.

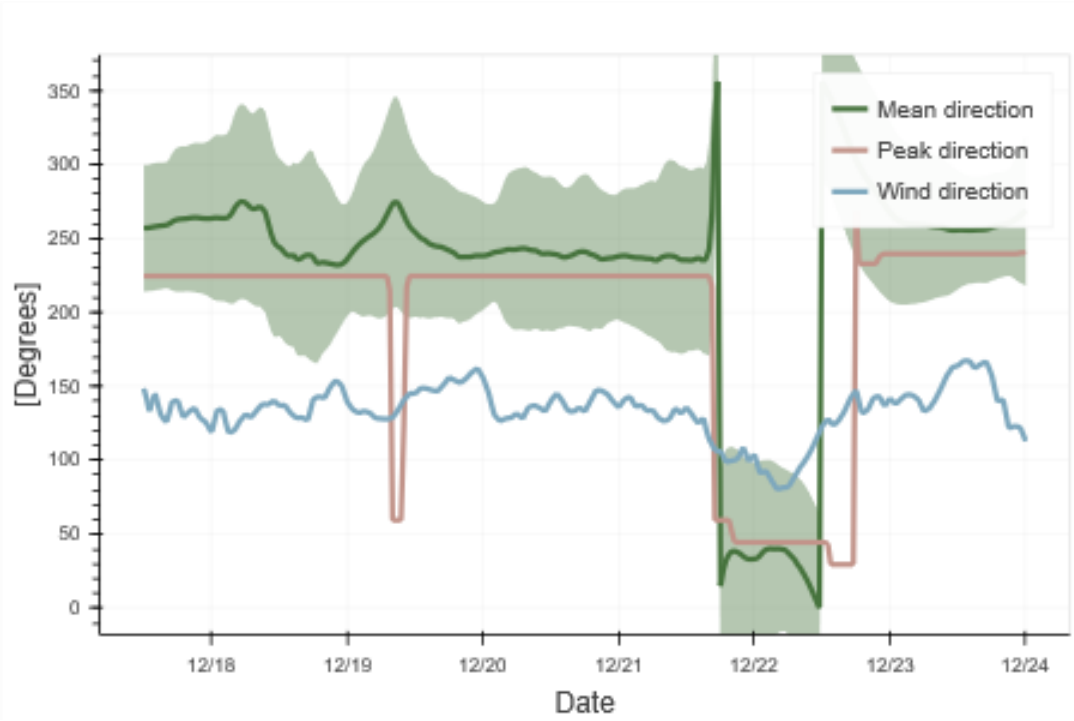

Figure 8: Saved figure from the DanWEC forecast website showing the prediction for the wave mean and peak direction and the wind direction over the next days.

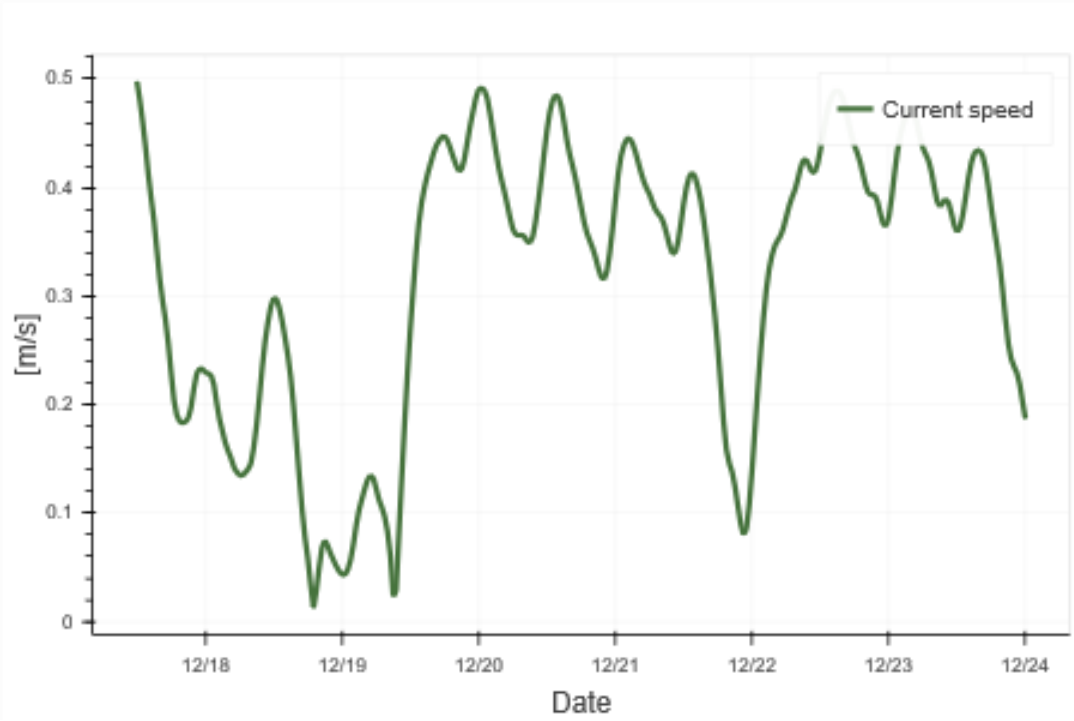

Figure 9: Saved figure from the DanWEC forecast website showing the prediction for the current speed over the next days.

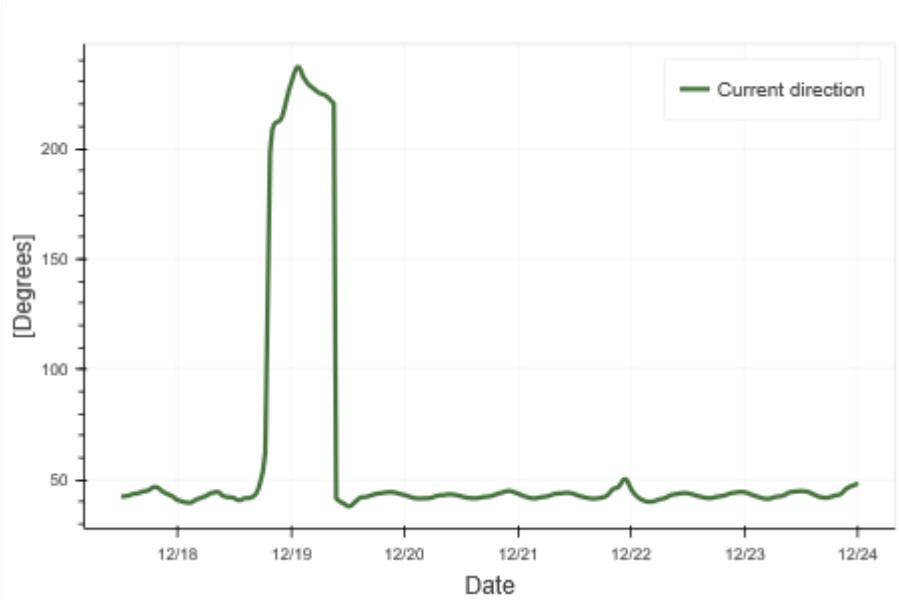

Figure 10: Saved figure from the DanWEC forecast website showing the prediction for the current direction over the next days.

It is important to mention that a zoom tool and pan tool are available for all figures on the website.

4 Example of the output from the O&M tool

DHI has developed a Forecast weather windows tool, referred as O&M tool (the reader is referred to [3] for more information on the tool) which has the capabilities of forecasting weather windows available for O&M activities scheduled for the DanWEC test site. The tool evaluates the downtime based on a metocean forecast dataset for the area of interest. The prediction of the metocean conditions can cover up to the next 144 hours (6 days, see previous section). The downtime of a specific activity was identified as the time interval during which any of these time series exceeded a fixed threshold. Within the 6 days forecast, the tool identifies the time windows that can accommodate the analysed O&M activity. The windows are ranked according to the lowest downtime.

Figure 11 and 12 are examples of outputs from the O&M tool. Figure 11 shows the probability of completion of an operation requiring waves under 1.5 m for a certain number of hours as a function of the month while Figure 12 shows the probability of completion of an operation requiring waves under 1.5 m as a function of the weather window length. This tool is available for DanWEC's operator and will be available for future user of the test site. On a day to day basis, this tool is overly complicated for DanWEC's operator but the information is highly relevant for new users at the site to plan their O&M activities on a yearly basis.

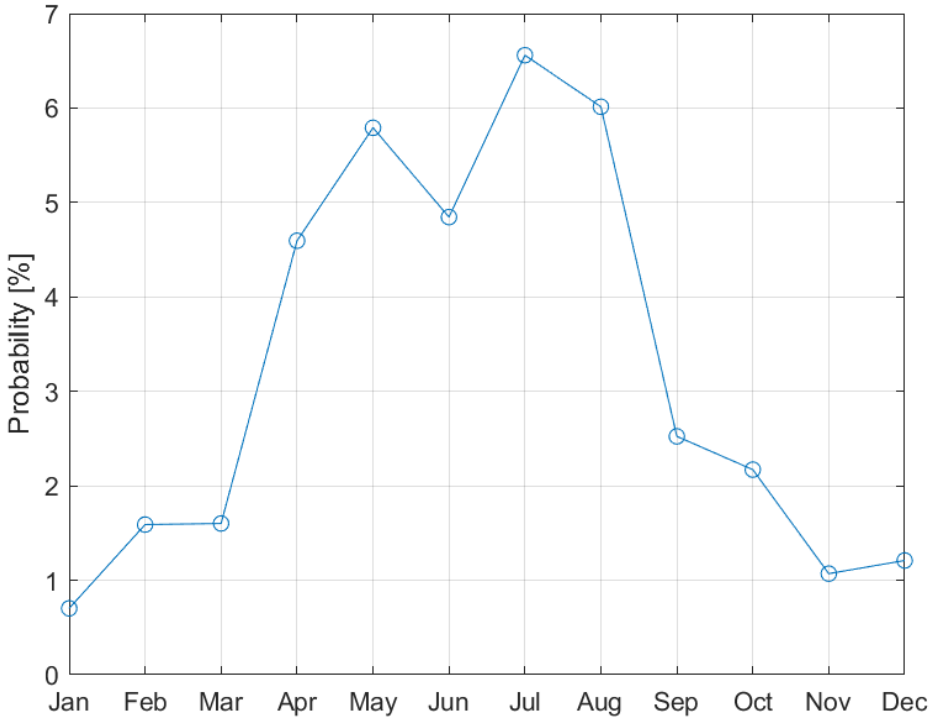

Figure 11: Probability of completion of an operation requiring waves under 1.5 m for a certain number of hours as a function of the month.

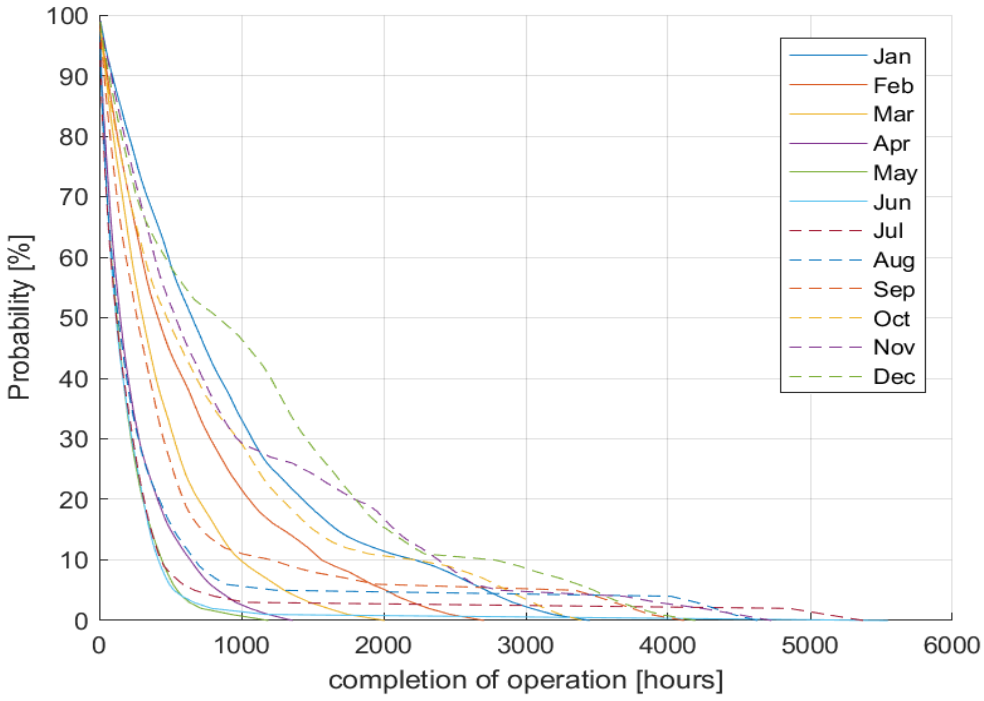

Figure 12: Probability of completion of an operation requiring waves under 1.5 m as a function of the weather window length.

5 Conclusions

The history of O&M on offshore wind turbines and also on the few wave energy devices that has been tested during longer periods (years), clearly shows that O&M is a major cost, and that there is a large potential to reduce the cost of energy (CoE) by improvements in the planning of the O&M. Electrical companies and potential and existing investors in wave energy technologies are aware of the risk of getting large O&M costs for such new technologies, and therefore the developers of wave energy devices uses large affords to demonstrate low O&M costs. It is, however, difficult to prove low O&M costs, and thereby convince investors about the feasibility of a given concept, without realistic validation by open water tests at large scale. Therefore having a good O&M tool and demonstrating the use of it in real tests is a major benefit for wave energy developers.

Apart from access to the test site at Hanstholm itself, DanWEC only have few products to offer existing and new customers. The main attractive asset by DanWEC are the wave riders which provides high quality real-time weather and wave data, which are available online to DanWEC's customers. The new forecasting and O&M tool add further value to the tools, which DanWEC can offer to the customers.

Getting new customers is essential for DanWEC to ensure the continuation of the centre. The new O&M tool is valuable not only for existing customers, but it is also valuable to DanWEC in order to attract new customers. DanWEC will use the tool in presentations of the company and to show demonstrations to potential new customers, thereby increasing the chance for getting new contracts for testing at the DanWEC site.

There are several wave energy test sites in the World and especially in Europe, and there are only few developers who are ready for open water testing in the real environment, so the competition among the existing test sites is strong. It is therefore important for DanWEC to have unique features and products to offer to the developers. The O&M tool developed specifically for DanWEC and the use for wave energy device operations is unique, and therefore provides a valuable feature for DanWEC to distinguish the company from the other existing and coming test sites.

Further future development and maintenance of the software is needed to ensure the tool to be up to date. New functions and updates should be included based on the coming experience with the system.

6 References

[1] Jensen, P. .: DanWEC EUDP, Establishment ofWave Hindcast. Technical report, DHI (2016).

[2] Tetu, A., Kofoed, J.P., Schlütter, F, and Hammer, P., Forecast Model for Current, Wave and Wind Climate at the Danish Test Site for Wave Energy, DanWEC. Proceedings for the International Conference on Time Series and Forecasting. 2018. p. 1328-1339.

[3] Tomasellli, P.D., Numerical Tool for Weather Window Prediction for O&M Activities, Technical report, DHI (2018).

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